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Family Name						
Given Name/s						
Student Number						
Teaching Period	Semester 1, 2018					

ENG474 – Power Systems Analysis	DURATION	
	Reading Time:	10 minutes
	Writing Time:	180 minutes
INSTRUCTIONS TO CANDIDATES		
<ol style="list-style-type: none"> 1. This examination is worth 50% of the total assessment for this unit. 2. Read the questions carefully before attempting. Attempt all questions. 3. Questions are not of equal value. 4. In order to explain your work, draw suitable (circuit) diagrams whenever possible. 5. Highlight the final answers. 6. Don't forget the units. Absence of a unit may cost you some credit. 		
EXAM CONDITIONS		
<u>You may begin writing from the commencement of the examination session.</u> The reading time indicated above is provided as a guide only.		
This is a CLOSED BOOK examination		
Any non-programmable calculator is permitted		
No handwritten notes are permitted		
No dictionaries are permitted		
ADDITIONAL AUTHORISED MATERIALS	EXAMINATION MATERIALS TO BE SUPPLIED	
No additional printed material is permitted	1 x 20 Page Book 1 x Scrap Paper	

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DOUBLE-SIDED.

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QUESTION 1 (15 marks)

Answer the following questions as briefly as possible. Long discussion is discouraged. Please use plain English and avoid mathematical expressions whenever possible. **(1 mark each)**

- Q1.1** In some transmission lines, two ground wires are used instead of one. Explain why.
- Q1.2** Draw the I-V characteristic of a Lightning arrester.
- Q1.3** Why are conductors stranded? Why are some stranded conductors have a steel core?
- Q1.4** When are conductors bundled? What are the benefits of bundled conductors?
- Q1.5** Due to skin effect, ac current tend to flow around the periphery of a conductor. But power engineers are not bothered about it at all. Why?
- Q1.6** Under what circuit conditions is Ferranti effect manifested?
- Q1.7** What is the reason for transposing long transmission lines?
- Q1.8** A transmission line has series impedance of $0+j0.5$ ohms/km and a shunt admittance of $0+j3$ μ S/km. Determine the Surge impedance of the line.
- Q1.9** An 500kV transmission line has a surge impedance of 350 ohms. Calculate the surge impedance loading (SIL) of the line.
- Q1.10** In automated load shedding what kind of relays are used?
- Q1.11** What is the advantage of a shell type transformer over a core type one? Any disadvantages?
- Q1.12** What is a relay? What does it do when there is no fault in the system?
- Q1.13** What is the difference between power transformers and instrument transformers?
- Q1.14** What is power system stability?
- Q1.15** What is the difference between equipment grounding and system grounding?

Go to next page for Question 2.

QUESTION 2 (5 marks)

Figure 2 shows a single line diagram of a 3-bus power system with 2 generation and one load buses. The numbers (other than the bus numbers 1, 2 and 3) in the figure are the per unit inductive reactances of lines or generators, as the case may be. Determine the Y_{bus} matrix for the system. Show all calculations and don't forget the unit(s).

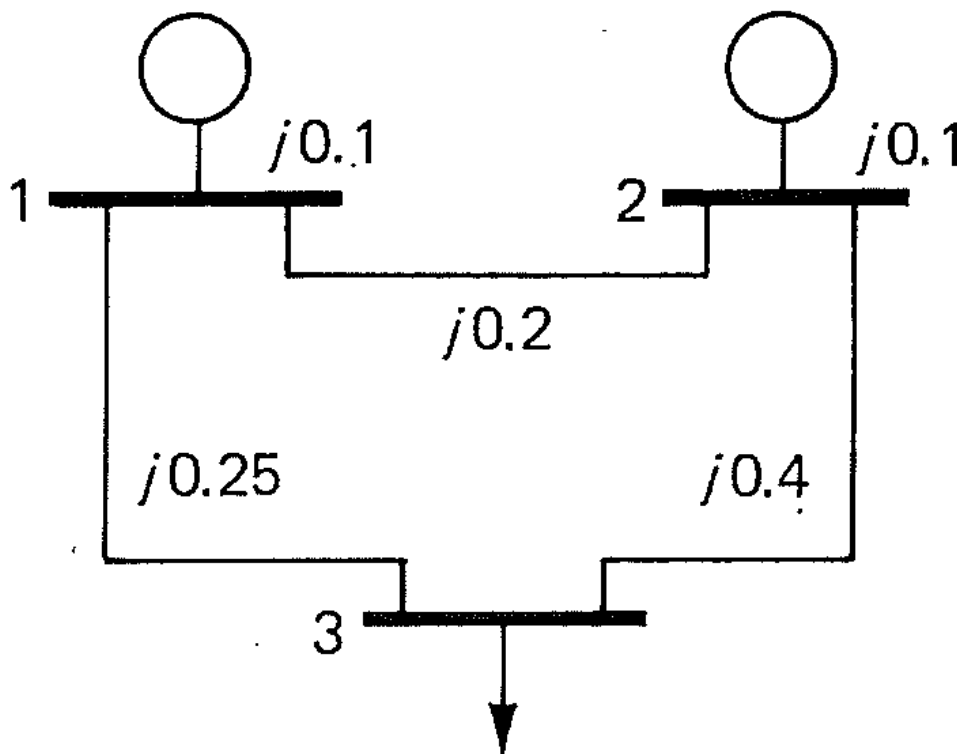


Figure 2. A simple power system for Question 2.1.
(Ref. B. Gungor, Power Systems, HBJ Publishers, 1988)

QUESTION 3 (10 marks)

Gauss-Seidel method is used for solving simultaneous equations in load flow studies. Determine V_1 and V_2 by solving the following two equations. Use Gauss-Seidel method and stop after the 5th iteration if you think the solution is leading to convergence. Take the initial values as $V_1 = V_2 = 0$.

$$\begin{aligned} V_1 + V_2 &= 2 \\ 3V_1 - 2V_2 &= 1.5 \end{aligned}$$

Go to next page for Question 4.

QUESTION 4 (20 marks)

Three power systems A, B and C are interconnected by tie-lines AB, BC and CA, as shown in Figure 3 below. From test on the three systems it is found that the power-frequency constants K_A , K_B and K_C are 650, 500 and 450 MW/Hz respectively. Lines AB and BC are protected so that after a time delay they trip out of service when the power transfer exceeds 300 and 120 MW respectively.

At a time when the system frequency is 50.00 Hz, system A is exporting 250 MW to system B and 100 MW to system C and system C is exporting 75 MW to system B, a fault takes place and line AC is tripped out of service.

Calculate the consequent frequencies attained by the separate systems and the power flows over any remaining lines.

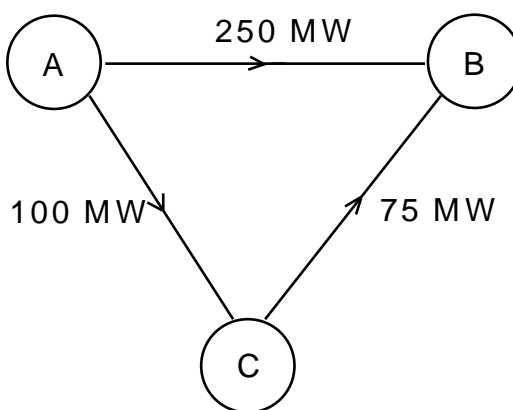


Figure 4. Diagram for Question 3.

THE END

FORMULAS

(Symbols have their usual meanings in the context of the particular formula)

Three phase circuits $S = \sqrt{3} V_L I_L$; $P = S \cos \phi$; $Q = S \sin \phi$

Per unit system $Z_{base} = \frac{(kV_{base})^2}{MVA_{base}}$; $Z_{pu2} = Z_{pu1} \times \frac{MVA_{base2}}{MVA_{base1}} \times \frac{(kV_{base1})^2}{(kV_{base2})^2}$

Lines $L = 0.2 \times \ln \frac{D_m}{D_s} \text{ mH/km}$; $C_N = \frac{1}{18 \times \ln \frac{D_m}{D_{sC}}} \mu\text{F/km}$; $Z_0 = \sqrt{\frac{z}{y}}$; $\gamma = \sqrt{zy}$.

ABCD parameters

	Short Line	Medium length line		Long Line	Long Line
		Nominal Pi Model	Nominal Tee Model	Exact Model	Approximate Model
A	1	$1 + YZ/2$	$1 + YZ/2$	$\cosh(\gamma \ell)$	$1 + YZ/2$
B	Z	Z	$Z(1 + YZ/4)$	$Z_0 \sinh(\gamma \ell)$	$Z(1 + YZ/6)$
C	0	$Y(1 + YZ/4)$	Y	$(1/Z_0) \sinh(\gamma \ell)$	$Y(1 + YZ/6)$
D	1	$1 + YZ/2$	$1 + YZ/2$	$\cosh(\gamma \ell)$	$1 + YZ/2$

$AD - BC = 1$; $A = D$ $P = \frac{EV}{X} \sin \delta$ $\Delta V \cong \frac{XQ}{V}$

	2-conductor bundle	3-conductor bundle	4-conductor bundle
D_s^b	$\sqrt{D_s \times d}$	$\sqrt[3]{D_s \times d^2}$	$1.09 \times \sqrt[4]{D_s \times d^3}$
D_{sC}^b	$\sqrt{r \times d}$	$\sqrt[3]{r \times d^2}$	$1.09 \times \sqrt[4]{r \times d^3}$

Voltage Regulation = $\frac{\text{No_load voltage} - \text{Full_load voltage}}{\text{Full_load voltage}} \times 100\%$

$\sum P_{ij} X_{ij} = 0$; $[I] = [Y][V]$; $P = \frac{|E| |V|}{X_s} \sin \delta$; $M = \frac{GH}{180 f} \text{ MJ-sec / deg-elec}$

$M \frac{d^2 \delta}{dt^2} = P_a = P_{mech} - P_{elec}$; $X_s = \frac{1}{\text{S.C.R.}}$

Power flow equations : $V_i = \frac{1}{Y_{ii}} \left(\frac{P_i - jQ_i}{V_i^*} - \sum_{\substack{k=1 \\ k \neq i}}^m Y_{ik} V_k \right)$; $Q_i = -\text{Im} \left\{ V_i^* \times \sum_{k=1}^m Y_{ik} V_k \right\}$

Symmetrical components

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} \quad \begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

Trigonometry:

$$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B \quad \cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$$

$$\sinh(\gamma l) = \sinh(\alpha l + j\beta l) = \sinh(\alpha l) \cos(\beta l) + j \cosh(\alpha l) \sin(\beta l)$$

$$\cosh(\gamma l) = \cosh(\alpha l + j\beta l) = \cosh(\alpha l) \cos(\beta l) + j \sinh(\alpha l) \sin(\beta l)$$

$$\text{Taylor series expansion : } f(x_1, x_2) \cong f^0(x_1, x_2) + \frac{\partial}{\partial x_1}(f(x_1, x_2)) \cdot \Delta x_1 + \frac{\partial}{\partial x_2}(f(x_1, x_2)) \cdot \Delta x_2$$